Journal of Orthopedics Research and Rehabilitation

Original Article

DOI: 10.51271/JORR-0033

Does scapular asymmetry affect shoulder joint position sense and muscle strength in adolescent idiopathic scoliosis? A pilot study

Mustafa Sarı[1], Merve Bütün[2], Nilgün Bek[1]

[1]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Lokman Hekim University, Ankara, Turkiye
[2]Department of Physiotherapy and Rehabilitation, Op. Dr Mahmut Ünal Practice, Ankara, Turkiye

Received: 01/05/2024 • Accepted: 14/06/2024 • Published: 09/07/2024

Corresponding Author: Mustafa Sarı, mustafa.sarri5353@gmail.com

ABSTRACT

Aims: The aim of this pilot study was to compare shoulder joint position sense (JPS) and shoulder muscle strength in individuals with adolescent idiopathic scoliosis (AIS) with and without scapular asymmetry and to analyze the results obtained in both groups in terms of convex and concave sides of the curve.

Methods: Individuals with AIS with primary right thoracic curvature and right dominant upper extremity were included in the study. The presence of scapular asymmetry was judged by Kibler's lateral scapular slide test. The study was completed with a total of 21 individuals with AIS, 10 with scapular asymmetry (asymmetrical group) and 11 without scapular asymmetry (symmetrical group). After the demographic and Cobb angle data of the individuals were obtained, other measurements were taken. JPS was evaluated by digital inclinometer at 60° shoulder flexion and 60° shoulder abduction positions. Shoulder flexion and abduction muscle strengths were evaluated with a handheld dynamometer. All measurements performed at of both extremities.

Results: There was no significant difference between the groups in terms of age, gender, body weight, height, body-mass index and Cobb angle ($p>0.05$). JPS of the concave side shoulder joint at 60 degrees of flexion had a statistically significant high in the asymmetrical group ($p=0.029$). In contrast, the angular deviation values of flexion and abduction motion were similar on the concave and convex sides in both groups ($p>0.05$). Shoulder muscle strength was similar between the asymmetrical and symmetrical groups ($p>0.05$). In the intra-group comparison of concave and convex side shoulder flexor and abductor muscle strengths in the asymmetrical group no difference was found ($p>0.05$); it was found that there was a significant low in the convex side shoulder abductor muscle strength within the symmetrical group ($p=0.023$).

Conclusion: The results of our study revealed that scapular asymmetry affects shoulder JPS in individuals with AIS but has no effect on muscle strength. Further studies with a higher number of subjects and objective measurement methods are needed for a more detailed evaluation of scapular kinematics, which directly affects soft tissues, in individuals with AIS.

Keywords: Kinematics, muscle strength, position sense, scapula, scoliosis, shoulder

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional deformity of the spine seen in 1-3% of the adolescent population, affecting girls more frequently and of unknown etiology.[1,2] This deformity not only causes progressive rotational deformation of the spine, but also affects the biomechanics of the upper and lower body segments for the affected areas.[3]

Pathologic changes in the thoracal region are common in spinal deformity.[4] Considering the close anatomical relationship between the thorax and the scapula, scapular asymmetry occurs in individuals with AIS due to pathologic displacement of the spine, disruption of the scapulothoracic rhythm, altered shoulder balance and compensation strategies. In a study examining the scapular kinematics of individuals with AIS, it was shown that the scapula on the convex side had more internal rotation and anterior tilt, while the scapula on the concave side had more external rotation, downward rotation and posterior tilt.[5] This proximal malalignment can negatively affect upper limb function by altering the kinetic chain and force transfer of the upper limb.[6]

Although the etiopathogenesis is still unclear, AIS is reported to be a multifactorial pathology.[7] Recent studies have shown

Cite this article: Sarı M, Bütün M, Bek N. Does scapular asymmetry affect shoulder joint position sense and muscle strength in adolescent idiopathic scoliosis? A pilot study. *J Orthop Res Rehabil.* 2024;2(3):49-54.

This work is licensed under a Creative Commons Attribution 4.0 International License.

that proprioceptive defects caused by mutations in certain genes responsible for proprioception (Runx3 and Piezo2) are associated with the development of AIS.[8,9] In some studies in which individuals with idiopathic scoliosis were compared with healthy controls, proprioceptive deficits were reported in the scoliosis group in the elbow, knee and neck regions.[10-12] Although clinical and laboratory studies have proven that individuals with AIS have impaired proprioception sensation of the elbow, knee and neck joints, the cause or effect of shoulder proprioception deficit is still unclear.[13,14]

Proprioception, the ability to perceive the position/movement of body segments, depends on feedback from mechanoreceptors (muscle spindles and golgi tendon organs) that respond to changes in muscle length and tone. In scoliosis, scapular disorientation, changes in scapular kinematics and periscapular muscle activity on both the convex and concave sides are known to be associated with spinal deformity.[15] Changes in the scapulothoracic joint and surrounding muscular tissue in individuals with AIS may affect the functional integrity and musculoskeletal alignment of the thorax-scapula-shoulder joint complex, resulting in differences in proprioceptive and muscular performance. Although scapular asymmetry and periscapular changes have been investigated in individuals with AIS, no study has been found to investigate the effect of these changes on shoulder joint proprioception and muscle strength. The aims of this pilot study were to investigate joint position sense (JPS), which is a sub-parameter of proprioception, and shoulder muscle strength in individuals with AIS with and without scapular asymmetry and to compare the results obtained in each group in terms of convex and concave sides of the curve.

As the hypothesis of this study, it was predicted that AIS patients with scapular asymmetry have poorer shoulder JPS and muscle strength and that this deficiency is more pronounced for the limb on the concave side of the curve.

METHODS

This cross-sectional study was conducted with patients who were referred to our clinic with a diagnosis of AIS who met the inclusion criteria. The study was carried out with the permission of Lokman Hekim University Scientific Researches Ethics Committee (Date: 30.01.2024, Decision No: 2024/8). The study was conducted in accordance with the Declaration of Helsinki. All individuals who volunteered to participate in the study were informed about the study and written informed consent was obtained.

Participants

Volunteers diagnosed with AIS, aged 10-18 years, with primary right thoracic curvature and right dominant upper extremity were included in the study. Individuals who had undergone any surgery on the spine or upper extremity, had pain or any injury to the shoulder joint, had any cervical lesion (disc herniation, thoracic outlet syndrome, etc.), had systemic or neurologic disorders, used a brace, and had problems with cooperation were excluded. Individuals with AIS who met the inclusion criteria were grouped according to the presence of scapular asymmetry using Kibler's lateral scapular slide test (LSST). The group of 21 subjects has been divided into two groups, 10 of which demonstrating the presence of scapular asymmetry and the remaining 11 demonstrating the absence of scapular asymmetry, whom we call symmetrical group.

Procedures

All participants were evaluated by a research physiotherapist (MS) at the same time of the day in a quiet and well-lit room. Age, gender, body weight and height were recorded as demographic information. Body-mass index (BMI) values were calculated. Cobb angles were measured and recorded on AP scoliosis radiographs to determine the angular severity of scoliosis.

Assessment of Scapular Asymmetry

Kibler's LSST was used to assess scapular asymmetry. The test was performed bilaterally in the standing position at three different shoulder abduction angles measured goniometrically (0°, 45°, and 90°, respectively). The measurements were performed first with the arms in a neutral position (0°) next to the trunk on both sides, then with the shoulders in 45° abduction, hands on the waist and thumbs pointing backwards, and finally with the shoulders in 90° abduction and maximum internal rotation (Figure 1).[16]

Scapular position was assessed by measuring the distance between the distal end of the scapula and the spinous process of the aligned thoracic vertebra. A difference of 1.5 cm or more between the two sides in any of the three test positions was considered scapular asymmetry.[17]

Assessment of JPS

Shoulder JPS was evaluated by active reposition test using a digital inclinometer. Measurements were performed at 60° flexion and 60° abduction positions of both extremities. Participants were asked to sit on a chair without armrests with their feet in full contact with the floor and knees in 90° flexion. The digital inclinometer was placed at the attachment point of the anterior part of the Deltoideus muscle to the humerus (Figure 2). The arm of the participants was flexed by the physiotherapist performing the test from the starting position of 0° to the target angle of 60° flexion, and after waiting in this position for 5 seconds, it was brought back to the starting position. The participant was then asked to close his/her eyes and actively use his/her arm to find this taught target angle. Participants verbalized the point at which they felt that they reached the target angle and maintained their position. The absolute difference between the target angle and the observed angle was measured and the absolute error score was calculated by averaging the three trials. The same measurements were repeated for the 60° abduction position of the shoulder. All measurements were performed bilaterally in both extremities.[18,19]

Assessment of Muscle Strength

Strength assessments were performed for the shoulder muscles responsible for flexion and abduction movements in which JPS tests were performed. Shoulder flexion and abduction muscle strength measurements were evaluated using a digital hand-hold dynamometer. Participants were asked to perform 90° flexion and 90° abduction of the shoulder joint in a sitting position with the elbow in extension and the palm pointing downwards. The dynamometer was placed 1-2 cm above the elbow joint and the participants were

asked to maintain their current position against the given resistance (Figure 3). Resistance was applied by the evaluator until the arm position was broken and the maximum strength obtained was noted in kg. Three measurements were taken for both dominant and non-dominate extremities and the average was recorded as the final score.[20]

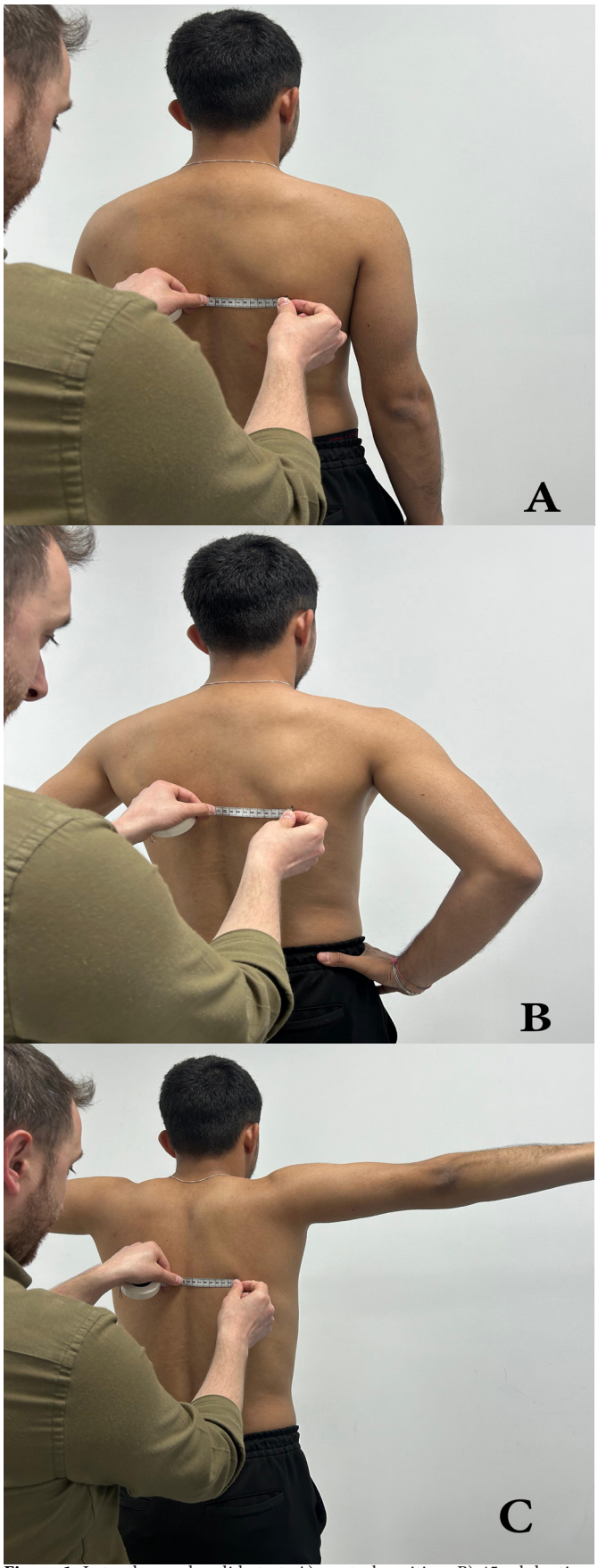

Figure 1. Lateral scapular slide test: A) neutral position, B) 45° abduction, C) 90° abduction

Figure 2. Assessment of joint position sense

Figure 3. Assessment of muscle strength

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 22.0 (SPSS Inc, Chicago, USA). All data were checked for normal distribution using the Shapiro-wilk test. Descriptive statistics were calculated for all variables and non-normal distributions were expressed as median and interquartile range (25-75), and ordinal variables were expressed as frequency and percentage. Mann Whitney u test and Chi-square test were used for intergroup comparisons and Wilcoxon signed-rank test was used for intragroup comparisons. Statistical significance value was accepted as $p<0.05$.

RESULTS

The pilot study was completed with 21 volunteer individuals with AIS (15 girls and 6 boys). The presence of scapular asymmetry determined by Kibler's LSST is shown in Figure 4.

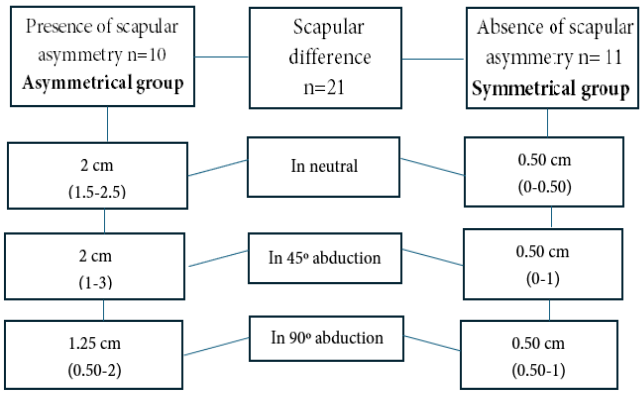

Figure 4. Evaluations of the presence of scapular asymmetry in individuals with AIS included in the study and LSST results of the groups [Median IQR (25-75)]

When the LSST results of the patients forming the groups were analyzed, a statistical difference was found between the asymmetry values in the neutral and 45 degrees abduction position (p<0.001). There was no significant difference between the groups in terms of age, gender, body weight, height, BMI and Cobb angle (p>0.05) (Table 1). When the groups were analyzed in terms of Cobb Angle values, although there was no statistical difference, it was observed that the angular severity of scoliosis was slightly higher in the group with scapular asymmetry.

Table 1. Comparison of demographic characteristics and Cobb angles of the groups

		Asymmetrical group (n=10) median IQR (25-75)	Symmetrical group (n=11) median IQR (25-75)	p
Age (year)		14 (13-15)	15 (13-18)	0.255[a]
Gender [n (%)]	Female	7 (70)	8 (72.7)	0.890[b]
	Male	3 (30)	3 (27.3)	
Body weight (kg)		53.50 (49-61)	50 (47-65)	1.000[a]
Height (cm)		167.50 (163-174)	167 (163-174)	0.724[a]
BMI (kg/m^2)		18.72 (18.04-20.81)	20.20 (17.21-21.80)	0.778[a]
Cobb angle (°)		20.02 (16-30)	18.97 (15-28)	0.642[a]

*p<0.05, [a]:Mann Whitney's u test, [b]:Chi-squared test, IQR: Interquartile range, BMI: Body mass index

Since the type of scoliosis was similar in all participants and the dominant upper extremity was right, the concave direction of the scoliotic curve was the non-dominant left upper extremity in all cases. In Table 2, statistical comparisons in terms of JPS and muscle strength were made both between groups using Mann-Whitney's u test (p[a]) and within groups using Wilcoxon signed-rank test comparing the concave-convex side (dominant-nondominant side respectively) (p[b]).

The shoulder joint movement deviation of the concave (non-dominant) side at 60 degrees of flexion of shoulder had a statistically significant high in the asymmetrical group (p=0.029). In contrast, the angular deviation values of flexion and abduction motion were similar on the concave and convex sides in both groups (p>0.05) (Table 2).

Table 2. Comparison of muscle strength and joint position sense of the within and between groups

	Outcome measures	Asymmetrical group (n=10) median IQR (25-75)	Symmetrical group (n=11) median IQR (25-75)	p[a]
Joint position sense (°)	60° flexion (convex)	4.17 (2.33-10.33)	5.66 (2-8.33)	1.000
	60° flexion (concave)	10.16 (4.66-13.33)	4.33 (2.33-8)	0.029*
	p[b]	0.092	1.000	
	60° abduction (convex)	6.33 (3-10.33)	4.66 (3.66-11)	0.751
	60° abduction (concave)	6.50 (2.66-10.33)	11.66 (3-12.66)	0.572
	p[b]	0.878	0.398	
Muscle strength (kg)	Flexion (convex)	11.38 (10.13-17.83)	11 (9.90-11.63)	0.805
	Flexion (concave)	11.46 (8.66-13.56)	11.26 (9.80-12.60)	0.888
	p[b]	0.508	0.656	
	Abduction (convex)	8.75 (8.30-12.43)	10.46 (8.16-10.63)	0.549
	Abduction (concave)	10.35 (7.46-14.10)	10.96 (10.43-12.40)	0.439
	p[b]	0.386	0.023*	

*p<0.05, a: Mann Whitney's u test; b: Wilcoxon signed-rank test, IQR: Interquartile range

Shoulder muscle strength was similar between the asymmetrical and symmetrical groups (p>0.05). In the intra-group comparison of concave and convex side shoulder flexor and abductor muscle strengths in the asymmetrical group, no difference was found (p>0.05); it was found that there was a significant low in the convex side shoulder abductor muscle strength within the symmetrical group (p=0.023) (Table 2).

DISCUSSION

In the study in which we evaluated the flexor and abductor muscle strength as well as the shoulder JPS in 60° flexion and abduction positions by grouping individuals with primary right thoracic scoliotic curve and dominant right upper extremity diagnosed with AIS between the ages of 10-18, according to the presence of scapular asymmetry, it was concluded that our hypotheses were partially confirmed. As a result of the study, the angle error values of the concave (non-dominant) side shoulder flexion movement were found to be higher in individuals with AIS who had only scapular asymmetry compared to those with symmetrical scapular alignment. In intragroup comparisons of the concave and convex sides of the subjects in both groups, only the concave side shoulder abductor muscle strength of the symmetrical subjects was statistically higher.

The scapula has a very important role in normal shoulder-arm biomechanics. Differences in the kinematics of the scapula can cause asymmetry and changes in periscapular muscle activation, affecting the position sense and muscle strength of the shoulder joint.[21] Reyhani et al.[6] compared shoulder proprioception in asymptomatic athletes with and without scapular dyskinesia and reported that the group with scapular dyskinesia had JPS deficits and that these differences were due to changes in muscle activity and scapular kinematics. Studies have shown that individuals with AIS also have changes in scapular kinematics and muscle activity.[5,22] The results of our study are consistent with the results of these studies in terms of showing that individuals with AIS with scapular asymmetry have a loss of shoulder JPS. In addition, since there is no study in the literature that

examines shoulder muscle strength and JPS in individuals with AIS taking scapular asymmetry into account, this pilot study is the first of its kind.

Proprioception is known as the afferent signal originating from joint, muscle, tendon and related deep tissue mechanoreceptors, and an intact proprioceptive function is essential for the control of normal movement.[23] Cook et al.[10] compared the elbow joint proprioception of healthy individuals and individuals with AIS and reported that individuals with AIS had higher scores in both treshold and angle repetition tests compared to healthy individuals. Similarly, Keessen et al.[24] reported that individuals with AIS have proprioceptive dysfunction compared to healthy individuals and this may be an important factor in the development of spinal asymmetry. It is seen that the scapula position was ignored in these studies comparing the upper extremity JPS of individuals with AIS and healthy individuals. Unlike the studies in the literature, our current study was performed only in individuals with AIS considering the presence of scapular asymmetry, and a significant difference was found between individuals with and without asymmetry in terms of concave side shoulder flexion JPS. This may be explained by the fact that scapular asymmetry affects the structures responsible for sagittal plane movements more than the frontal plane.

Gupta and Shukla compared the proprioception of the elbow joint between healthy individuals and individuals with AIS and reported that there was a significant difference between the groups, but there was no difference between the dominant and non-dominant side within both groups.[25] The finding that the convex and concave side shoulder JPS of individuals with AIS were similar in the present study is in parallel with the results of previous studies. Yağcı et al.[26] examined the curve pattern and upper extremity function changes in individuals with AIS and reported that concave side dexterity and hand reaction time decreased in individuals with main thoracic curvature. This may have been caused by asymmetry in the scapula affecting the concave side JPS. We believe that the asymmetry in the scapula may affect the concave side JPS in individuals with AIS with main thoracic curvature, further negatively affecting dexterity and hand reaction time.

The scapula is an important part of the kinetic chain that allows the sequential transfer of forces, and inadequate muscle strength and muscle activation in the kinetic chain can lead to dysfunction.[27] Many studies have reported that altered muscle length-tension relationships in individuals with scapular asymmetry may lead to a decrease in shoulder girdle muscle strength.[28,29] However, Barbosa et al.[30] compared the physical performance of the upper limb in asymptomatic healthy adults with and without dyskinesia and reported that both groups had similar results and that the presence of scapular dyskinesia was not the only factor associated with poor scores on the upper limb performance test. Similarly, Akınoğlu et al.[15] reported similar horizontal abduction and horizontal adduction muscle strength results in athletes with and without scapular asymmetry. As a result of the present study, it was observed that there was no difference between the groups in terms of the presence of scapular asymmetry in shoulder flexion and abduction muscle strength of individuals with AIS. This is in line with the results of previous studies.

Seitz et al.[28] reported that athletes with dyskinesia had less lower trapezius and serratus anterior muscle strength compared to those without dyskinesia and that this was due to decreased upward rotation of the scapula. Lin et al.[22] examined the relationship between scapular kinematics and muscle activity in individuals with AIS and found that there was decreased lower trapezius and serratus anterior muscle activity on the concave side, while there was an increase in upward rotation of the scapula. They also reported that shoulder dysfunction did not occur on the concave side, whereas it may occur on the convex side. In the light of this information, the reason why the shoulder abduction muscle strength of individuals without scapular asymmetry was significantly higher on the concave side may be due to the relationship between the upward rotation movement of the scapula and muscle activation.

Considering the presence of scapular asymmetry in individuals with AIS in shoulder JPS and muscle strength assessments is a strength of this study. The evaluation of scapular asymmetry with LSTT and the relatively small sample size can be considered as limitations of this pilot study.

CONCLUSION

As a result of our study, there was a difference between individuals with AIS with and without scapular asymmetry in terms of shoulder flexion JPS on the concave side, while other position sensations and muscle strengths were similar. When the convex and concave sides were compared within the groups, only the symmetrical scapula group had significantly better concave side shoulder abductor strength. The results of our study revealed that scapular asymmetry affects shoulder JPS in individuals with AIS but has no effect on muscle strength. Further studies with a higher number of subjects and objective measurement methods are needed for a more detailed evaluation of scapular kinematics, which directly affects soft tissues, in individuals with AIS.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Lokman Hekim University Scientific Researches Ethics Committee (Date: 30.01.2024, Decision No: 2024/8).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declared that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Konieczny MR, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. *J Child Orthop.* 2013;7(1):3-9.
2. Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. *Lancet.* 2008;371(9623):1527-1537.
3. Raso VJ, Lou E, Hill DL, Mahood JK, Moreau MJ, Durdle NG. Trunk distortion in adolescent idiopathic scoliosis. *J Pediatr Orthop.* 1998; 18(2):222-226.
4. LeBlanc R, Labelle H, Rivard CH, Poitras B. Relation between adolescent idiopathic scoliosis and morphologic somatotypes. *Spine.* 1997;22(21):2532-2536.
5. Turgut E, Gur G, Ayhan C, Yakut Y, Baltaci G. Scapular kinematics in adolescent idiopathic scoliosis: A three-dimensional motion analysis during multiplanar humeral elevation. *J Biomech.* 2017;61:224-231.
6. Reyhani F, Meftahi N, Rojhani-Shirazi Z. Comparing shoulder proprioception, upper extremity dynamic stability, and hand grip strength in overhead athletes with and without scapular dyskinesis. *J Bodyw Mov Ther.* 2024;39:304-310.
7. Cheng JC, Castelein RM, Chu WC, et al. Adolescent idiopathic scoliosis. *Nat Rev Dis Primers.* 2015;1(1):1-21.
8. Blecher R, Krief S, Galili T, et al. The proprioceptive system masterminds spinal alignment: insight into the mechanism of scoliosis. *Dev Cell.* 2017;42(4):388-399.
9. Chesler AT, Szczot M, Bharucha-Goebel D, et al. The role of PIEZO2 in human mechanosensation. *N Engl J Med.* 2016;375(14):1355-1364.
10. Cook SD, Harding AF, Burke SW, Whitecloud TS, Barrack RL, Leinhardt TM. Upper extremity proprioception in idiopathic scoliosis. *Clin Orthop Relat Res.* 1986;213:118-124.
11. Barrack RL, Whitecloud TS, Burke SW, Cook SD, Harding AF. Proprioception in idiopathic scoliosis. *Spine.* 1984;9(7):681-685.
12. Guyot MA, Agnani O, Peyrodie L, Samantha D, Donze C, Catanzariti JF. Cervicocephalic relocation test to evaluate cervical proprioception in adolescent idiopathic scoliosis. *Eur Spine J.* 2016;25:3130-3136.
13. Le Berre M, Guyot MA, Agnani O, et al. Clinical balance tests, proprioceptive system and adolescent idiopathic scoliosis. *Eur Spine J.* 2017;26:1638-1644.
14. Lau KK, Law KK, Kwan KY, Cheung JP, Cheung KM, Wong AY. Timely revisit of proprioceptive deficits in adolescent idiopathic scoliosis: a systematic review and meta-analysis. *Global Spine J.* 2022;12(8):1852-1861.
15. Akınoğlu B, Kabak B, Balci A, Kocahan T, Hasanoğlu A. A comparative study of shoulder muscle strength, sense of proprioception and internal/external rotation flexibility between adolescent athletes with and without scapular asymmetry. *Adv Rehab.* 2020;34(3):1-7.
16. Ben Kibler W. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26(2):325-337.
17. Curtis T, Roush JR. The lateral scapular slide test: a reliability study of males with and without shoulder pathology. *N Am J Sports Phys Ther.* 2006;1(3):140-146.
18. Dover G, Powers ME. Reliability of joint position sense and force-reproduction measures during internal and external rotation of the shoulder. *J Athl Train.* 2003;38(4):304-310.
19. Yang JL, Chen S, Jan MH, Lin YF, Lin JJ. Proprioception assessment in subjects with idiopathic loss of shoulder range of motion: joint position sense and a novel proprioceptive feedback index. *J Orthop Res.* 2008; 26(9):1218-1224.
20. Beshay N, Lam PH, Murrell GA. Assessing the reliability of shoulder strength measurement: hand-held versus fixed dynamometry. *Shoulder Elbow.* 2011;3(4):244-251.
21. Karagiannakis D, Athanasopoulos S, Mandalidis D. Scapular muscles' activity in female volleyball players with scapular asymmetry in the resting position. *J Bodyw Mov Ther.* 2018;22(3):580-585.
22. Lin JJ, Chen WH, Chen PQ, Tsauo JY. Alteration in shoulder kinematics and associated muscle activity in people with idiopathic scoliosis. *Spine.* 2010;35(11):1151-1157.
23. Chen N, Chen C, Mo X, Du Q, Liu Y. Joint proprioception of adolescent idiopathic scoliosis: a mini review. *Biomed J Sci Tech Res.* 2019;15(5): 11601-11603.
24. Keessen W, Crowe A, Hearn M. Proprioceptive accuracy in idiopathic scoliosis. *J Pediatr Orthop.* 1992;12(4):149-155.
25. Gupta RR, Shukla Y. To study the upper extremity proprioception in juvenile idiopathic scoliosis-an observational study. *Indian J Physic Therapy.* 2014;2(2):66-69.
26. Yagci G, Aydin Ozcan D, Ayhan C, Demirkiran G, Yakut Y, Yazici M. Evaluation of upper extremity function and its relation to curve pattern in female adolescents with idiopathic scoliosis: a pilot study. *Spine Deform.* 2020;8:1175-1183.
27. Sciascia A, Cromwell R. Kinetic chain rehabilitation: a theoretical framework. *Rehabil Res Pract.* 2012;2012:1-9.
28. Seitz AL, McClelland RI, Jones WJ, Jean RA, Kardouni JR. A comparison of change in 3D scapular kinematics with maximal contractions and force production with scapular muscle tests between asymptomatic overhead athletes with and without scapular dyskinesis. *Int J Sports Phys Ther.* 2015;10(3):309-318.
29. Merolla G, De Santis E, Campi F, Paladini P, Porcellini G. Supraspinatus and infraspinatus weakness in overhead athletes with scapular dyskinesis: strength assessment before and after restoration of scapular musculature balance. *Musculoskelet Surg.* 2010;94:119-125.
30. Barbosa GMP, Matheus JPC, Lemos TV, Barbosa GMP, Souza Júnior JRD. Comparison of the upper extremity physical performance tests between asymptomatic adults with and without scapular dyskinesis. *Fisioter. Mov.* 2023;36:e36121.